

# Transfer information

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References: TPE Procedure N1004-026

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Attachment (Reference doc.) : .....

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Attachment (Reference doc.) : .....

Transfer information : .....

Process add your remark and comments

\* A = Action / I = For information

Transfer information to	Initial	Action *
<input type="checkbox"/> Projects (X)	.....	.....
<input type="checkbox"/> DC / Cost Control (B)	.....	.....
<input type="checkbox"/> Electrical (E)	.....	.....
<input type="checkbox"/> Instrumentation (I)	.....	.....
<input type="checkbox"/> Software (S)	.....	.....
<input type="checkbox"/> Piping (P)	.....	.....
<input type="checkbox"/> Mechanical (M)	.....	.....
<input type="checkbox"/> Civil (C)	.....	.....
<input type="checkbox"/> Structural (C)	.....	.....
<input checked="" type="checkbox"/> Process (T)	EBE	A
<input type="checkbox"/> HVAC (W)	.....	.....
<input checked="" type="checkbox"/> Process	HHH	I
<input checked="" type="checkbox"/> Process	GJR	I

## Continued action / reaction receiver

Action or reaction ..... :  
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Name Lead Engineer : ..... Initial : BSA Date : 05.02.15  
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Reply to: All recipients and file the original incl. attachments in the Project File

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# HANDY MANUAL

## Program “FLARESIM”

### (Version 4.0)

Gas Dispersion



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# Introduction

Flaresim includes two types of gas dispersion model intended for two different types of analysis:

- A jet dispersion calculation models dispersion of flared fluid close to the tip to identify the potential for dangerous gas concentrations in flame out conditions.
- A Gaussian dispersion calculation models dispersion of flared fluid or combustion products over longer distances.

The purpose of this document is to illustrate how to use each of these models and to analyse the gas dispersion around the flare in normal operation and flame out conditions.

The examples begin with gas jet dispersion analysis of relieved fluid and the dispersion of H<sub>2</sub>S in the event of a flame out condition and with the dispersion of combustion gases from burning. The examples attempt to highlight multiple dispersion objects carried out for different calculations.

- Example 1 – Gas Jet Dispersion
- Example 2 – H<sub>2</sub>S Gas Gaussian Dispersion Contour Plot
- Example 3 – Combustion Gases Gaussian Dispersion Line Plot

Flaresim Dispersion is applicable to analysis a single pollutant or multiple pollutants. The source of pollutants is either the combustion gases or the components in the relieved fluid.

# Gas Dispersion

The Dispersion provides a Gaussian dispersion calculation to model the dispersion of combustion gases from burning flares and dispersion of relieved fluid in the event of a flame out condition. Gaussian dispersion is a simple model of gas dispersion appropriate for a first pass screening of emissions from a flare system. In its current implementation in Flaresim it is suitable for buoyant fluids only and does not include modeling of terrain or structure effects, both of which can have a significant impact on dispersion results.

## Example 1 – Gas Jet Dispersion

The jet dispersion analysis for flammable gas concentrations is based on the Cleaver & Edwards jet dispersion model which is regarded as a reasonable model for concentrations close to the source.

In this example gas jet dispersion will be studied in case when the flammable gas concentrations around the flare in the event of a flame out.

The following data will be used in the example.

### Flared Fluid

Methane	0.9 mole frac
Ethane	0.08 mole frac
H <sub>2</sub> S	0.02 mole frac
Temperature	75 °C
Ref Pressure	1.013 bara
Flow	50,000 kg/hr

### Mechanical Data

Tip Diameter	387.4 mm (16 in)
Tip Length	1 m
Stack location	At origin (0, 0, 0)
Stack Length	20 m
Stack orientation	Vertical

### Environment Data

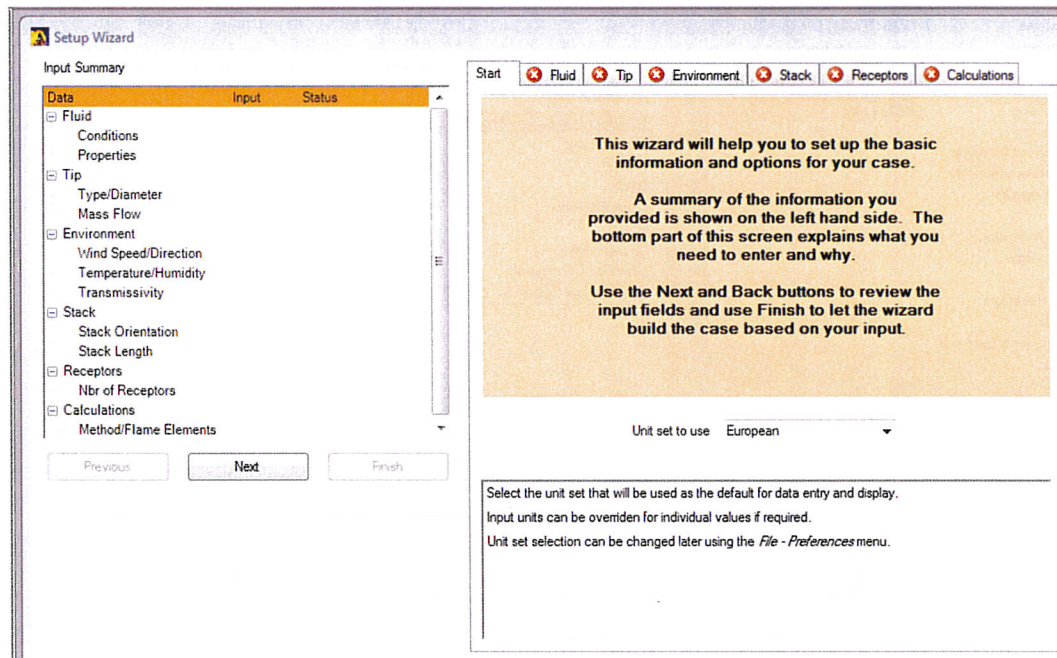
Temperature	15 °C
Wind	10 m/s from North

## Initial Setup

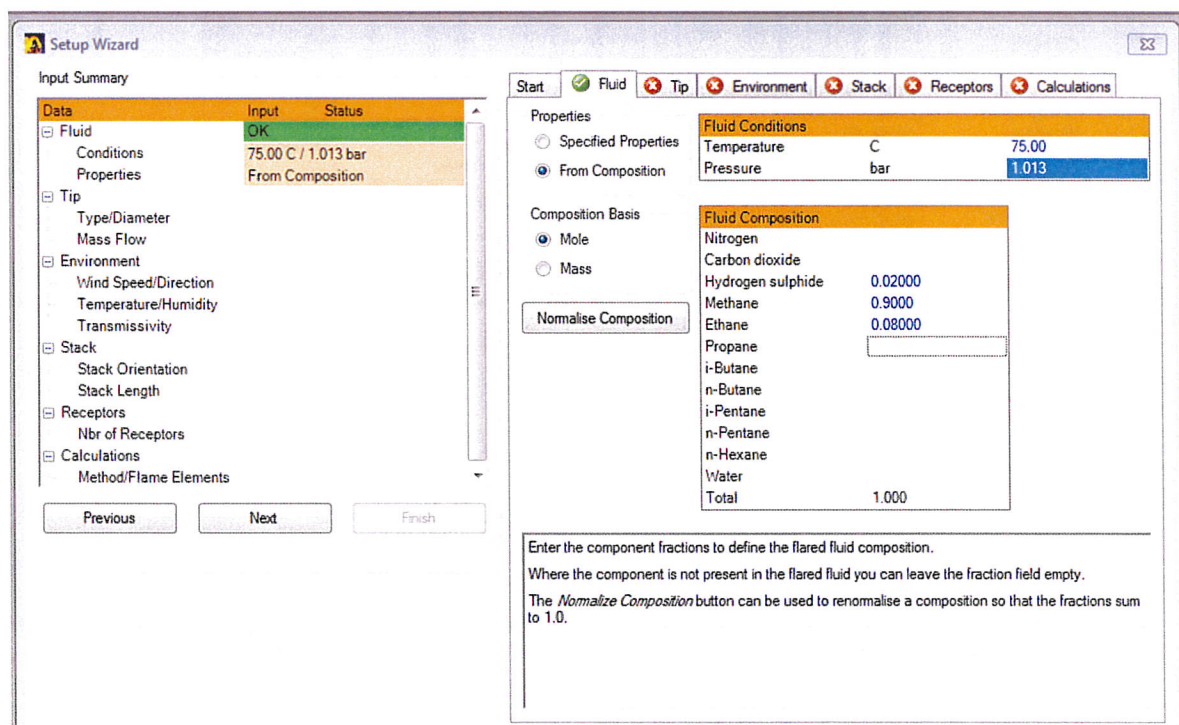
1. Start the Flaresim program.



2. In the opening, set the unit to European Field as shown. Work through the Fluid, Tip, Environment and Stack tabs entering the data defined above. Once you have entered the Stack data then click the Finish button.



The finished view of the Fluid, Tip, and Stack tabs are shown below:



**Setup Wizard** 83

Input Summary

Data	Input	Status
<input checked="" type="checkbox"/> Fluid	OK	
Conditions	75.00 C / 1.013 bar	
Properties	From Composition	
<input checked="" type="checkbox"/> Tip	OK	
Type/Diameter	Pipe / 387.4 mm	
Mass Flow	50000 kg/h	
<input checked="" type="checkbox"/> Environment		
Wind Speed/Direction		
Temperature/Humidity		
Transmissivity		
<input checked="" type="checkbox"/> Stack		
Stack Orientation		
Stack Length		
<input checked="" type="checkbox"/> Receptors		
Nbr of Receptors		
<input checked="" type="checkbox"/> Calculations		
Method/Flame Elements		

Previous Next Finish

Start ☒ Fluid ☒ Tip ☒ Environment ☒ Stack ☒ Receptors ☒ Calculations

Tip Type

☒ Pipe Tip

☐ Sonic Tip

Tip Sizing

Fluid Mass Flow Rate	kg/h	50000
Tip Diameter	mm	387.4
Mach Number		0.4137

F Factor Method

F Factor Method	
Natural Gas	<input type="checkbox"/>
Tan	<input type="checkbox"/>
Kent	<input type="checkbox"/>
High Efficiency	<input type="checkbox"/>
Cook	<input type="checkbox"/>
Generic Pipe	<input checked="" type="checkbox"/>
Modified Chamberlain	<input type="checkbox"/>
User/Vendor Specified	<input type="checkbox"/>

Proprietary **Flaresim** correlation based on refitting Kent, Tan, Natural Gas and Cook methods across a range of exit velocities and molecular weights.

A conservative general purpose method

For gases, either the pipe or sonic tip types may be selected.

Pipe flares are the simplest type of tip and may be specified for both high and low pressure gases.

If the pressure available is greater than 2 bar (30 psi) at the tip then a sonic tip can be utilised. Sonic flare tips have the advantage of low flame emissivities due to more efficient combustion of the flare gas.

For lower pressures a pipe flare is generally used possibly with steam or air assistance

**Setup Wizard** 83

Input Summary

Data	Input	Status
<input checked="" type="checkbox"/> Fluid	OK	
Conditions	75.00 C / 1.013 bar	
Properties	From Composition	
<input checked="" type="checkbox"/> Tip	OK	
Type/Diameter	Pipe / 387.4 mm	
Mass Flow	50000 kg/h	
<input checked="" type="checkbox"/> Environment	OK	
Wind Speed/Direction	10.00 m/s from 0	
Temperature/Humidity	15.00 C / 10.00 %	
Transmissivity	UserSpecified / 1.000	
<input checked="" type="checkbox"/> Stack	OK	
Stack Orientation	Vertical / INTO Wind	
Stack Length	Do Sizing Calculation	
<input checked="" type="checkbox"/> Receptors	OK	
Nbr of Receptors	1 Point	
<input checked="" type="checkbox"/> Calculations	OK	
Method/Flame Elements	Brzustowski / 1	

Previous Next Finish

Start ☒ Fluid ☒ Tip ☒ Environment ☒ Stack ☒ Receptors ☒ Calculations

Environment Data

Wind Speed	m/s	10.00
Wind Direction	°	0
Temperature	C	15.00
Humidity	%	10.00
Transmissivity Spec.		1.000
Transmissivity Method		UserSpecified
Solar Radiation	kW/m2	0.8000

Include Solar Radiation ☒

Wind direction is from North

The direction **from** which the wind blows.

Generally the worst or prevalent wind direction can be determined by examination of the wind rose for the site in question.

Wind angle from North = 0, East = 90, South = 180, West = 270.



**Setup Wizard**

Input Summary

Data	Input	Status
Fluid	OK	
Conditions	75.00 C / 1.013 bar	
Properties	From Composition	
Tip	OK	
Type/Diameter	Pipe / 387.4 mm	
Mass Flow	50000 kg/h	
Environment	OK	
Wind Speed/Direction	10.00 m/s from 0	
Temperature/Humidity	15.00 C / 10.00 %	
Transmissivity	UserSpecified / 1.000	
Stack	OK	
Stack Orientation	Vertical / INTO Wind	
Stack Length	20.00 m	
Receptors	OK	
Nbr of Receptors	1 Point	
Calculations	OK	
Method/Flame Elements	Brzustowski / 1	

Previous Next Finish

Start ☒ Fluid ☒ Tip ☒ Environment ☒ Stack ☒ Receptors ☒ Calculations

**Stack Angle**

Vertical ☒  
60° from Horizontal ☐  
45° from Horizontal ☐  
Horizontal ☐  
User Defined ☐

**Stack Data**

Angle from Horizontal	°	90.00
Angle from North	°	0
Length	m	20.00

The angle of the stack to North must be specified, though this is not important for vertical stacks.  
By default the angle of the stack to North will be set so that it points into the wind direction specified on the Environment tab but the this value can be updated.  
Generally the worst radiation case will be found with the stack pointing directly into the wind.  
Range: 0 to 360 degrees.

- Before enabling the jet dispersion calculations, create a new Receptor Grid to see the results more clearly. Select the Receptor Grid branch in the Case Navigator and click the Add button. In the new view enter the following data.

Name = Elevation  
Grid Plane = Elevation-Northing  
Grid Offset = 0 m  
Elevation Minimum = -100 m  
Elevation Maximum = 300 m  
Northing Minimum = -300 m  
Northing Maximum = 100 m

Leave remaining values at defaults.

Receptor Grid

Name: Elevation

Max Radiation | Plot Overlay | Graphic Report

Extent | Radiation | Noise | Temperature | Concentrations

Grid Extent

Grid Extent		
Grid Plane	Elevation-Northing	
Easting Offset	m	0
Elevation		
Minimum	m	-100.0
Maximum	m	300.0
Number of Points	41	
Northing		
Minimum	m	-300.0
Maximum	m	100.0
Number of Points	41	

Properties

Grid Point Properties		
Point orientation	None	
Emissivity	0.7000	
Absorptivity	0.7000	
Area Ratio	2.000	
Options		
Noise basis	Noise	

Delete Ready Ignored

- Open the Calculation Options view by selecting it in the Case Navigator and clicking the view button. Select the check box labeled Jet Dispersion in the Include Options section of the General Tab.

Calculation Options

General | Sizing & Pressure Profile | Heat Transfer | Emissions | Fitting

Calculation Methods

Methods		
Radiation Method	Brzustowski	
No. Flame Elements	1	
Element Position	%	50.00
Noise Method	Spectrum	

Options

☐ Expert Mode

Include Options			
Wind Chill	<input type="checkbox"/>	Atm. Noise Attenuation	<input checked="" type="checkbox"/>
Jet Dispersion	<input checked="" type="checkbox"/>	Gaussian Dispersion	<input type="checkbox"/>
Run Dynamics	<input type="checkbox"/>	Run Case Studies	<input checked="" type="checkbox"/>

Buoyancy

Buoyancy		
Pipe Burner	m/s	3.048
Sonic Burner	m/s	4.572
Well Test Burner	m/s	0.03048

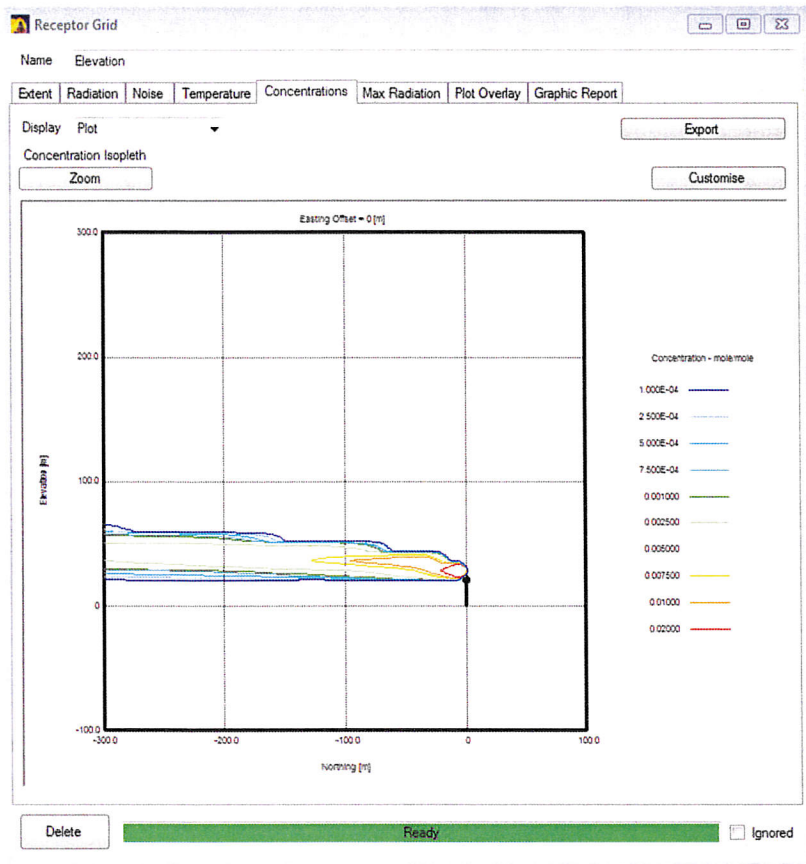
Environment

Active Environment: Environment 1

Ready

## Initial Calculations

The design is ready to run. Click the Calculate button. The background of the Errors/Warnings log will be yellow indicating a warning message. Checking this it warns of the jet interacting with the ground at a distance of 2152m which is not a problem.



The jet dispersion calculation shows the concentrations of the flare fluid in the event of a flame out and is useful for establishing the regions in which a flammable gas concentration may be obtained.

## Example 2 – Gas Gaussian Dispersion Contour Plot

The Gaussian dispersion calculates the combustion gases and flared fluid over longer distances and uses a simpler theoretical model that does not include detailed terrain effects.

In this example the dispersion of H<sub>2</sub>S from the flare tip in the event of a flame out will be studied.

### Initial Setup

1. Create a Dispersion Object by selecting the Dispersion branch in the Case Navigator and clicking the Add button. In the Dispersion view enter the following data on the Input Data tab as shown below.

Name = H<sub>2</sub>S Contour

Pollutant Source = Flared Fluid

Calculation Type = Contour Plot

Contours Height = 0 m

Northing Minimum = -1000 m

Northing Maximum = 0 m

Easting Minimum = -500 m

Easting Maximum = 500 m

Number of points, Northing and Easting = 41

2. On the Pollutant Data tab select the H<sub>2</sub>S component only. For a contour plot, only one component can be selected.

The screenshot shows the 'Gaussian Dispersion' dialog box with the 'Input Data' tab selected. The configuration is as follows:

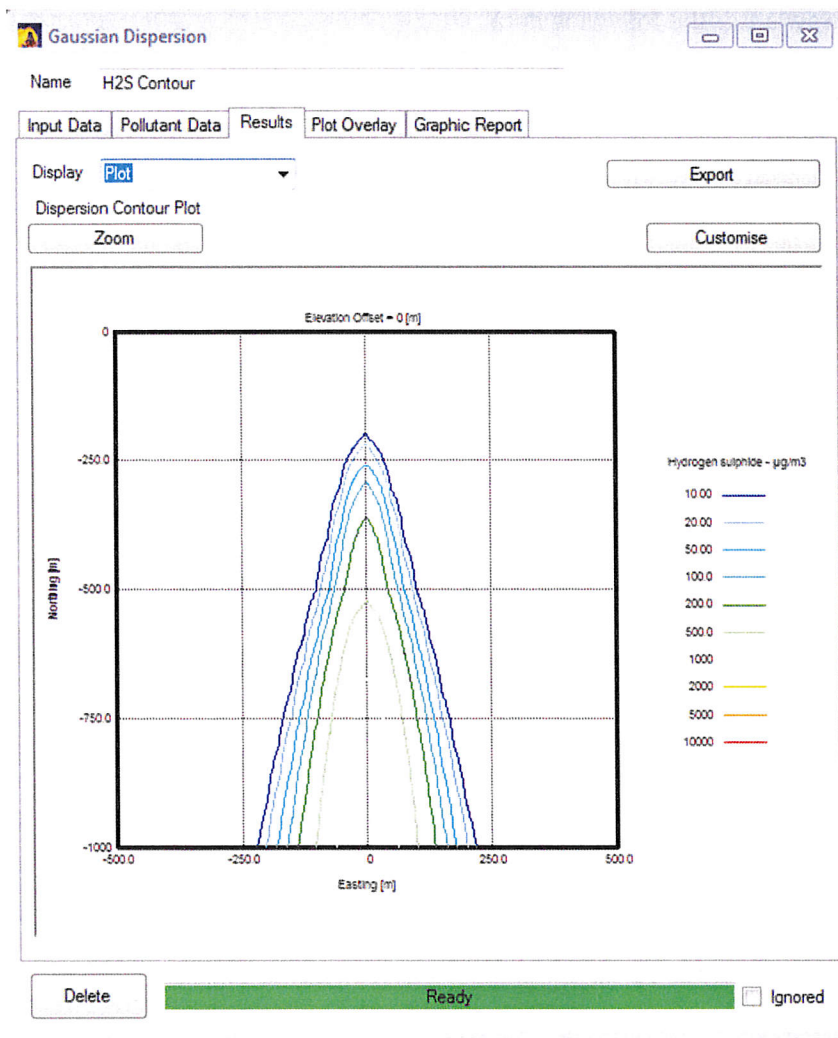
- Name:** H<sub>2</sub>S Contour
- Source Type:** Pollutant source (radio button), ☐ Combustion Product, ☒ Unburnt Flared Fluid
- Calculation Details:** Calculation Type (radio button), ☒ Contour Plot, ☐ Downwind Line Plot
- Contour Plot Extent:**
  - Contours Height: m, 0
  - Northing:**
    - Minimum: m, -1000
    - Maximum: m, 0
    - Number of Points: 41
  - Easting:**
    - Minimum: m, -500.0
    - Maximum: m, 500.0
    - Number of Points: 41
- Buttons:** Delete, Ready (highlighted in green), Ignored (disabled)
- Footer:** Dispersion calculations are disabled, use Calculation Options to activate

3. Open the Calculation Options view and select the Gaussian Dispersion checkbox to enable these calculations.

## Initial Calculations

The design is ready to run. Click the Calculate button.

Select the Results tab and then the Plot option for the display. The plot shows the ground level concentration contours for H2S downwind of the stack as shown below.





## Example 3 – Gas Gaussian Dispersion Line Plot

In this example the downwind concentrations of pollutants in the combustion gases of the flare when it is operating will be studied.

### Initial Setup

In the Case Navigator select the Dispersion branch and click Add to create a new dispersion object.

1. In the Input Data tab of its view enter the following data.

Name = Combustion Emissions

Pollutant Source = Combustion Gas

Calculation Type = Downwind Line Plot

Line through Point = Origin

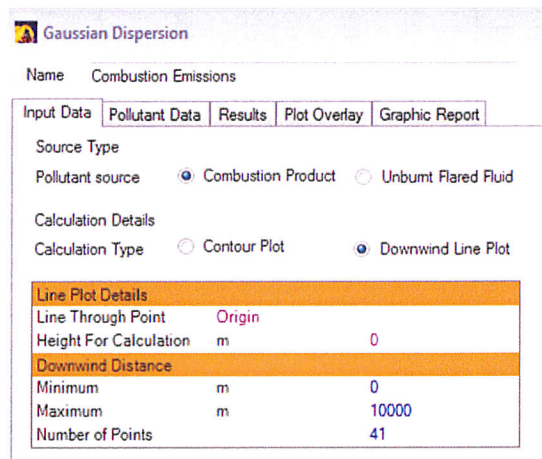
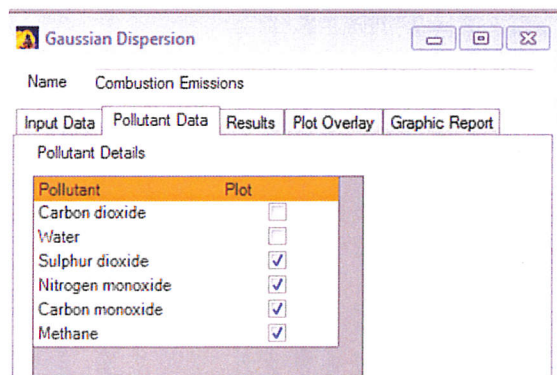
Height for Calculation = 0 m

Downwind Distance Minimum = 0 m

Downwind Distance Maximum = 10000 m

Number of points = 41

2. Select the Pollutant tab and select the SO<sub>2</sub>, NO, CO and Methane pollutants for calculation by checking the box alongside these components.



3. Since the dispersion of the combustion gases will be dependent on the flame temperature, it can be set. Hence open the Tip View and select the Fluids tab. At the bottom of this view you may input a value for the flame temperature or clear the specified value to allow it to be calculated from the specified combustion air ratio.
4. Set the Combustion Air ratio to 3.0 and clear the specified flame temperature.

Tip

Name Tip 1

Results

Noise Results

Flame Shape

Combustion Results

Purge Gas

Details

Noise Input

Location & Dimensions

Fluids

Emissions

Fluids

Primary Fluid

Fluid	Fluid 1	
Mass Flow	kg/h	50000
Mole Flow	kgmole/s	0.7925

Assist Fluid

Fluid		
Mass Flow	kg/h	
Flow Ratio		

Flow vs Time

Combustion Input

Combustion Input Data

Combustion Air Ratio	3.000	
Flame Temp. (opt)	C	

Clear Flame Temperature to allow it to be calculated

Delete

Ready

☐ Ignored

- Open the Environment view and set the Atm. Stability Class to PasquillB.

## Initial Calculations

The design is ready to run. Click the Calculate button.

Return to the Combustion Gas Results tab of the Tip view to see the calculated flame temperature of 721 °C and the combustion gas compositions.

**Tip**

Name: Tip 1

Details | Noise Input | Location & Dimensions | Fluids | Emissions

Results | Noise Results | Flame Shape | Combustion Results | Purge Gas

Flame Temperatures

Calculated Flame Temperatures

Adiabatic Flame Temp.	C	851.8
Calc'd Flame Temp.	C	720.9

Combustion Gases - Mass

Combustion gas flows - mass basis

Carbon dioxide	kg/h	133090
Water	kg/h	105874
Oxygen	kg/h	385258
Nitrogen	kg/h	1.903E+06
Sulphur dioxide	kg/h	3655
Nitrogen monoxide	kg/h	70.65

Combustion Gases - Mole

Combustion gas flows - mole basis

Carbon dioxide	kgmole/s	0.8400
Water	kgmole/s	1.632
Oxygen	kgmole/s	3.344
Nitrogen	kgmole/s	18.87
Sulphur dioxide	kgmole/s	0.01585
Nitrogen monoxide	kgmole/s	6.529E-04

Delete Ready Ignored

In the Combustion Gas dispersion view go to the results page and select the plot result to view the results as shown below. The peak concentration of SO<sub>2</sub> is calculated at 68 µg/m<sup>3</sup> at a distance of approximately 1500 m downwind of the flare tip

